

## 17.4 CHANGES TO THE NCEP SREF SYSTEM AND THEIR IMPACT ON CONVECTIVE FORECASTING

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### 1. INTRODUCTION

Despite many advances in mesoscale numerical modeling, forecasting in the 0-2 day time period continues to be restrained by a combination of initial condition uncertainty and errors in model parameterizations. NCEP began running a Short-Range Ensemble Forecasting (SREF) system (Tracton et al, 1998), with the goal of capturing the uncertainty in the forecast process, in developmental mode in 1996, with the system becoming operational in 2001. Feedback from users at Environmental Modeling Center model reviews, though, has indicated that the actual uncertainty associated with the short-range forecast process has not been adequately sampled by the operational system. The contributions of different model physics are to some extent captured by running 5 members with a version of the Eta model with the Betts-Miller-Janjic (BMJ) convective parameterization (Betts 1986, Janjic 1994), another 5 with the Eta run with the Kain-Fritsch (KF) parameterization (Kain and Fritsch 1993), and 5 members using the Regional Spectral Model (RSM), run with the Simplified Arakawa Schubert scheme. (Arakawa and Schubert 1974). This configuration, however, often results in 3 distinct clusters of 5 members each.

EMC has implemented a new SREF system in the late summer of 2004. This system attempts to have greater accounting for the uncertainty in the parameterizations of the models while maintaining the role of initial condition uncertainty. The amount of possible changes to the model physics is infinite; this version of the SREF uses different convective parameterizations. For the Eta members, 3 members are run with the BMJ scheme (a control and two members with initial condition perturbations), 3 members are run with the KF scheme (again, 1 control and 2 perturbed), and four runs are made using different versions of

the BMJ and KF schemes. The extra BMJ members use a set of more moist reference profiles to delay the onset of deep convection, as the pure scheme tends to overturn too early in the day. The KF runs use enhanced detrainment of convective condensate onto the grid scale, again with the goal of delaying the onset of deep convection. There are five RSM members, 2 perturbed runs with the SAS and 3 runs (one control and 2 perturbed) with a relaxed Arakawa-Schubert convective parameterization. (Moorthi and Suarez, 1999).

### 2. WARM SEASON HEAVY RAINFALL

Warm season model precipitation forecasts are influenced heavily by the choice of convective scheme, so the previous configuration of the SREF with only 3 convective parameterizations inevitably led to an unreasonably small spread in model solutions. Even in scenarios in which the precipitation in later forecast periods would be highly dependent upon the exact evolution of deep convection in earlier periods, the SREF was prone to give unreasonably high confidence to heavy amounts in very localized regions. Fig. 1 shows a sample forecast of the probability of greater than one inch of rainfall occurring in a particular 24-hour period comprising a "day 2" forecast.

In Fig. 1, the SREF indicates a 90 per cent likelihood of greater than 1.0 inches of rain over northwest Kansas. This is a remarkably high percentage for any convective scenario with modest forcing, but it is even more unrealistic given that there is a "day one" of convective evolution that will occur before the relevant period begins. The chances of many ensemble members correctly predicting a localized area of heavy convective rainfall, of which the mesoscale evolution will be determined by how well the members handle an initial period of convective activity, certainly do not warrant such high confidence. The precipitation verification shown in Fig. 2 shows that the heavy rain indeed did not fall where predicted by the SREF

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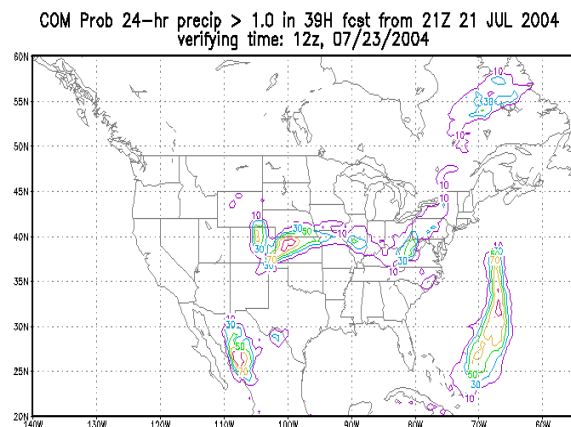


Fig. 1: 39-hour- forecast of the probability of greater than 1.0 inches of precipitation in the operational SREF in the 24 hour period ending at 1200 UTC 23 July 2004.

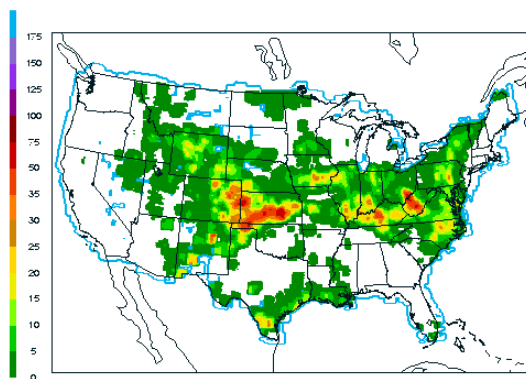


Fig. 2. Observed precipitation (mm) in the 24-hour period ending 1200 UTC 23 July 2004. Analysis is the 1/8 degree precipitation analysis from the Climate Prediction Center.

The new version of the SREF, however, shows a much more realistic set of probabilities for this case. Like the plot from the operational SREF, the region of emphasis is placed too far to the north. Only a very small area, however, is given a 70 per cent or greater probability of greater than one inch of rain, clearly demonstrating a more realistic amount of spread for this warm-season convective event with weak forcing.

Further proof of more spread within the new SREF presents itself quite nicely in the precipitation verification statistics. Fig. 4 shows the bias scores for the means of the operational Eta and the new and old versions of the SREF. The mean of the new SREF displays a dramatic

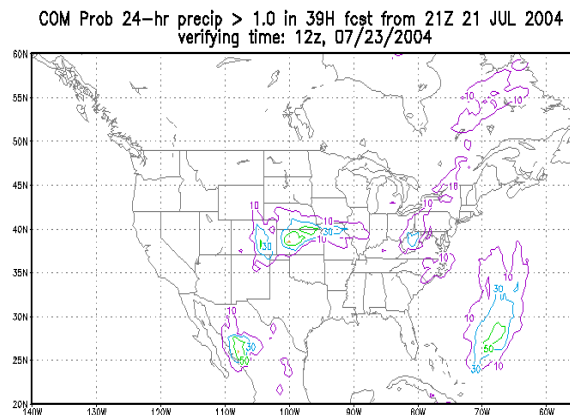


Fig. 3. Same as in Fig. 1, except for the parallel version of the SREF (which became operational in August 2004).

dry bias at higher amounts than the mean of the old version of the SREF. This might suggest that the members of the new configuration are failing to capture heavy rainfall events. Instead, the better explanation appears to be that this is a result of increased spread. This leads to the rainfall maxima from different members being located in different positions, with the mean values effectively reducing the amounts at any one location. It is hypothetically possible for each member to predict a 3-inch maximum for a given case, but if each one is in a different location, the mean field will not show any values anywhere close to 3 inches.

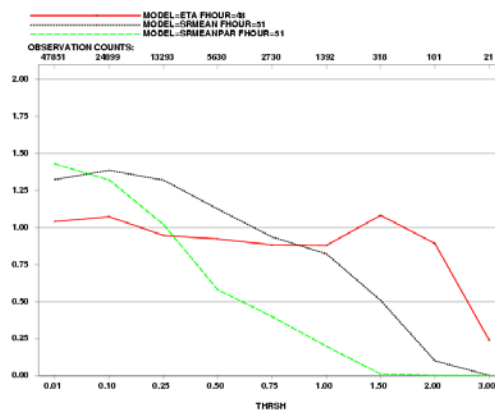


Fig. 4: 48-hour precipitation forecast bias scores for the operational Eta (red), the old SREF (gray), and the new SREF (green). Amount thresholds are listed along the x-axis.

This explanation is substantiated by looking at the bias scores for all individual members in Fig. 5. The majority of individual members have biases greater than 1.0 for many of the higher amounts for which the mean of the ensemble shows a dry bias. It is therefore likely that the increased spread of the new system is leading to a dry mean forecast, suggesting that the spread of precipitation forecasts must be examined in addition to the mean, and individual solutions should be examined when possible. SREF users accustomed to the behavior of the system when warm-season spread was limited are encouraged to revisit the issue of convective precipitation forecasting.

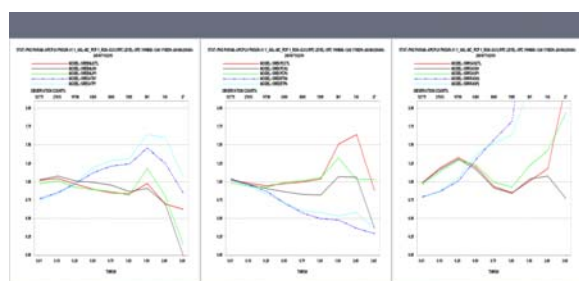


Fig. 5. Bias scores for all members of the new SREF. The first set is for all of the BMJ and modified BMJ members, the second set is for the KF members, and the third set is for the RSM members. Precipitation amount thresholds are listed along the x-axis.

### 3. INSTABILITY

The forecasts of convective available potential energy (CAPE) from the different members often display very different characteristics. A case from July 2004 in which a couple of tornadic supercells developed over north-central Illinois before forming a bow echo that raced southeast generating widespread wind damage across Kentucky and Tennessee (Fig. 6) is examined. From the RUC analysis of CAPE at the time corresponding to when the derecho was moving across western Kentucky (Fig. 7), it is apparent that a northwest to southeast instability axis was in place from southern Illinois across the Louisville, Kentucky area into west-central Tennessee. (It should be noted that the RUC CAPE values represent more of a moist static energy, with maximum values typically inflated, so the large region of 5500+ values is almost certainly overdone but still indicative of extreme instability in place over that region)

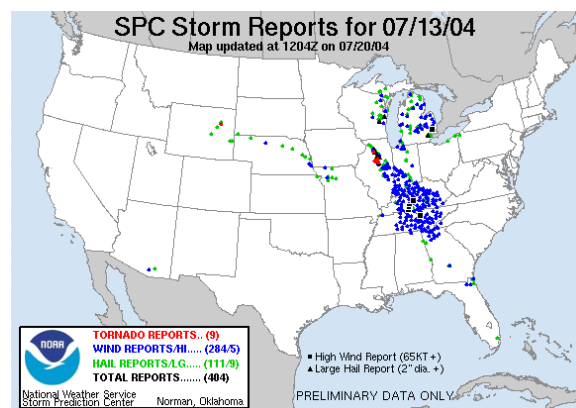


Fig. 6. Severe reports received by the Storm Prediction Center (NCEP/SPC) for 13 July 2004. Red dots indicate tornadoes, blue dots represent severe wind, and green dots are severe hail. Black indicates a significant event.

The 39-hour CAPE forecast from the BMJ control run is shown in Fig. 8. The forecast is overall fairly skillful (judged by comparing to the analysis), but it is deficient in the one of the most critical regions relevant to this case; there is a minimum value in the region where Illinois, Indiana, and Kentucky meet. The KF control run, shown in Fig. 9, does a better job in this region. It should also be noted that the KF run has a dramatically different solution over the Gulf of Mexico and the southeast U.S. coast; results are mixed, although the truth of the verifying analysis over water can be questioned.

The CAPE forecast from one of the Eta members with more moist BMJ reference profiles is shown in Fig. 10. The northwest-southeast instability axis through which the derecho propagated is shown quite nicely. Values overall are higher than those from the KF run and significantly higher than those from the BMJ control run. Examination of the members on a daily basis in the summer of 2004 has found that this hierarchy is quite common. Fig. 11 shows the forecast from one of the RSM members. CAPE in the Illinois/Iowa vicinity is quite large but drops off dramatically to the south and east. The RSM members have typically shown much lower values of CAPE and much less coverage of strong instability during the summer of 2004, although a possible computational error is being investigated at the time of this writing.



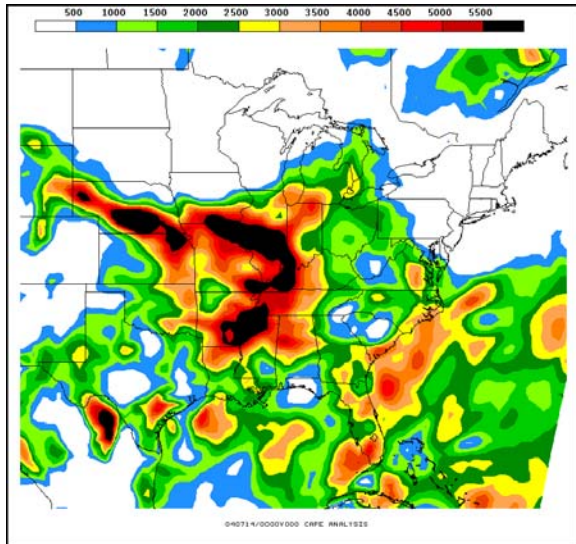


Fig. 7. 00-hr analysis of CAPE from the RUC model, valid 0000 UTC 14 July 2004.

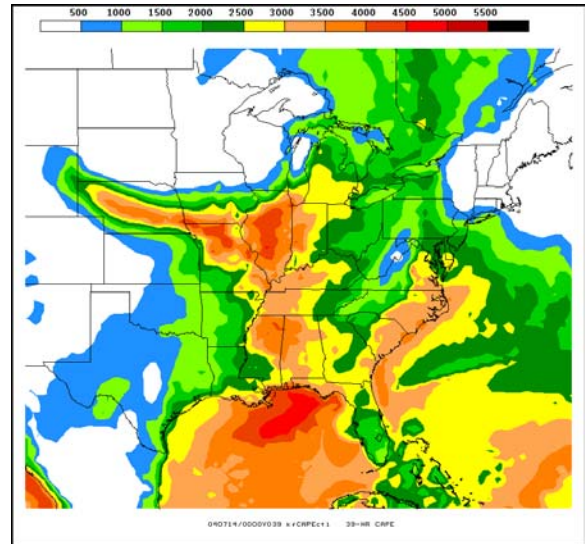


Fig. 9. Same as in Fig. 8, except for the Eta Kain-Fritsch control run.

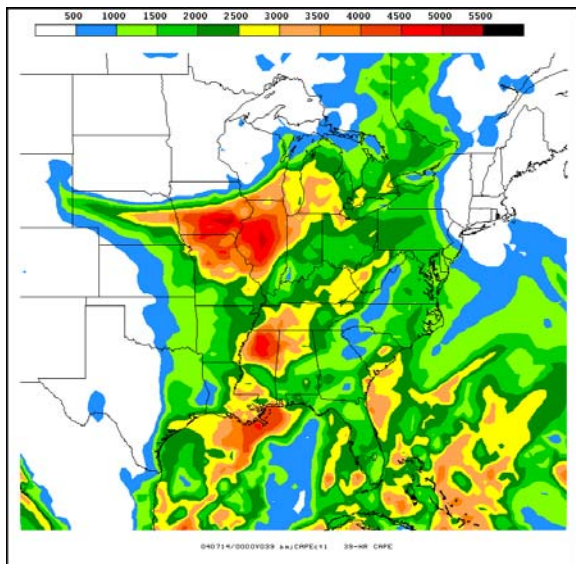


Fig 8. 39-hour forecast of CAPE from the BMJ control run, valid 0000 UTC 14 July 2004.

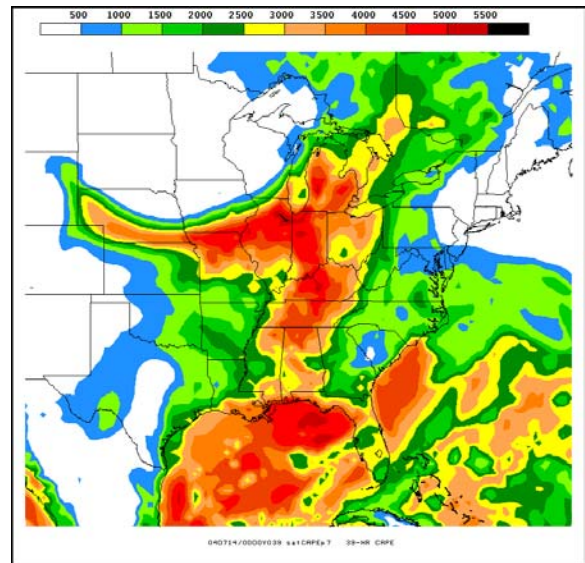


Fig. 10. Same as in Fig. 8, except for one of the perturbed runs with a version of the BMJ convective scheme with more moist reference profiles.

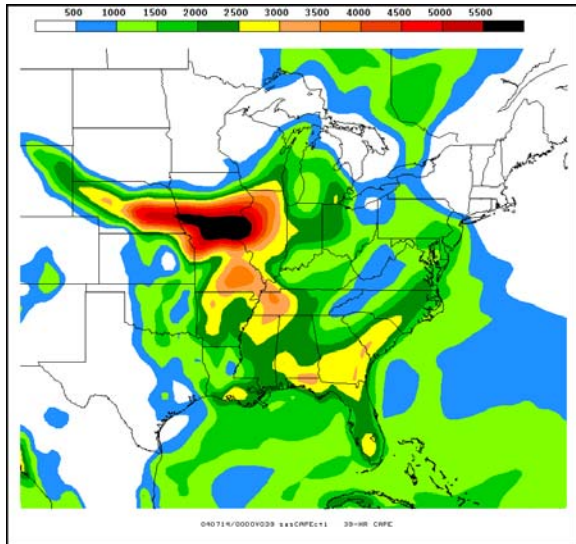


Fig. 11. Same as in Fig. 8, except for the RSM control run with the SAS convective scheme.

#### 4. SOUNDING STRUCTURE

Using different convective schemes with their different treatments of processes that most affect sounding structure often leads to a significant spread within the forecast soundings. In particular, the BMJ and KF schemes have been shown to differ quite dramatically in this regard (Baldwin et al., 2000), largely due to shallow convection.

Some examples of different characteristics of the behaviors of different members are shown in this section which compares 39-hour forecast soundings for Nashville, Tennessee to the verification for the case shown in section 3. Fig. 12 shows one of the BMJ members. It shows a common problem of the BMJ; the cap is eliminated by shallow convective processes which cool the layer at the inversion and warm a layer above. A representative KF member, though, shown in Fig. 13 is a far superior forecast. Fig. 14 shows one of the biases of the members using the more moist BMJ reference profiles. It often generates saturated, unstable layers in the low to middle levels of the atmosphere. This may occur due to the delayed onset of deep convection in an environment in which there is a need to have the instability released.

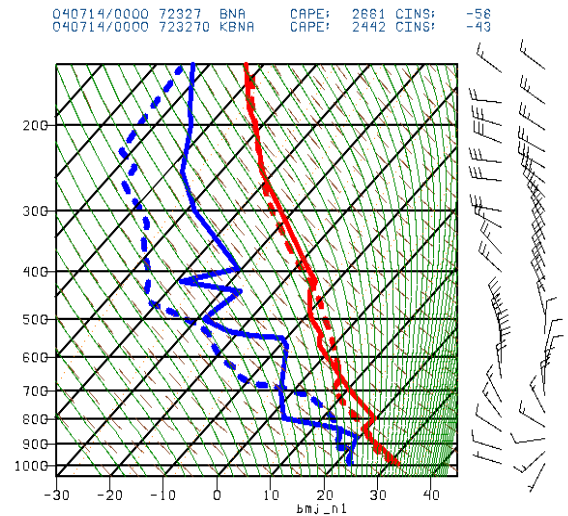


Fig. 12. Observed (solid) and 39-hour forecast (dashed) soundings for Nashville, Tennessee valid 0000 UTC 14 July 2004. Red lines represent temperature with blue lines represent dew point. The top line of the convective parameter information and left wind column are observed; the second line and right column are forecast. The forecast is the Eta control run with the BMJ convective scheme.

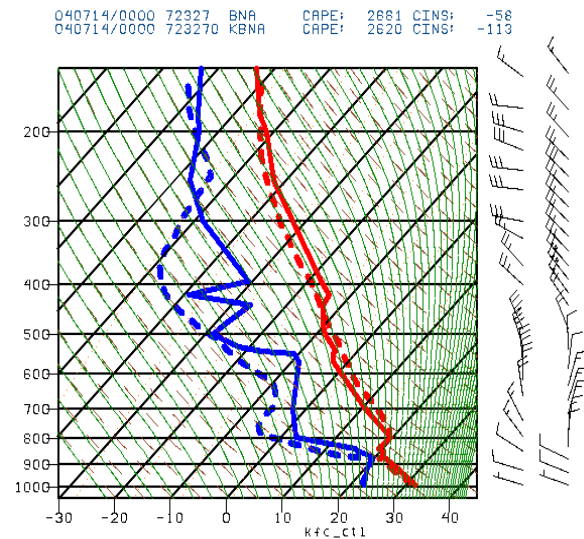


Fig. 13. Same as in Fig. 12, except for one of the Eta members with the KF convective scheme.



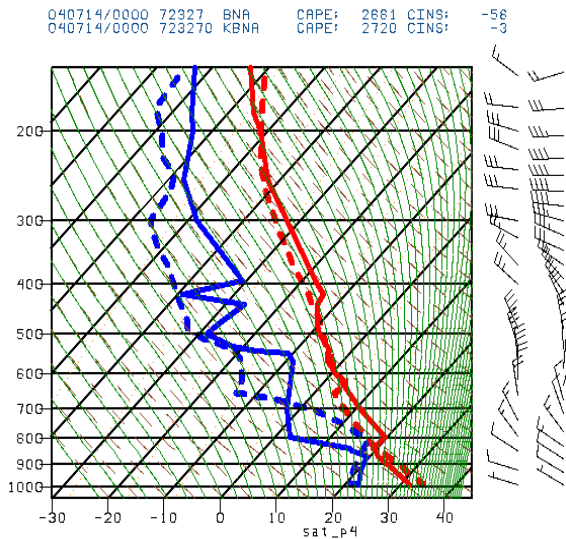


Fig. 14. Same as in Fig. 11, except for one of the Eta members with the version of the BMJ code using more moist reference profiles.

## 5. ONE FINAL CASE

The potential for the SREF to add value to the convective forecasting process is demonstrated in the case of 23 August 2004 in which several supercells developed over northeast Kansas late in the early evening, producing a few tornadoes along with hail and wind damage (including one significant hail report) (Fig. 15).

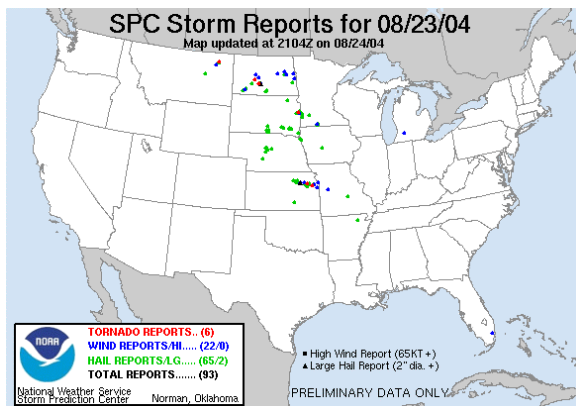


Fig. 15. Same as in Fig. 6, except for 23 August 2004.

The operational Eta predicted that widespread convective precipitation would break out over much of eastern Kansas much earlier in the day (not shown), overturning the atmosphere and leading to limited instability available late in the day (Fig. 16). Instead, the RUC analysis in Fig. 17 indicates that the atmosphere was extremely

unstable over much of eastern Kansas (as well as over much of the central plains). The mean from all members of the SREF (Fig. 18) is a significant improvement over the operational Eta, showing over 2500 J/kg over eastern Kansas. The values increase if we look at the mean from only the Eta SREF members to eliminate the RSM low cape bias (Fig. 19). Neither the Eta nor any SREF mean, though, properly destabilizes the atmosphere over North Dakota, with the SREF a slightly worse forecast.

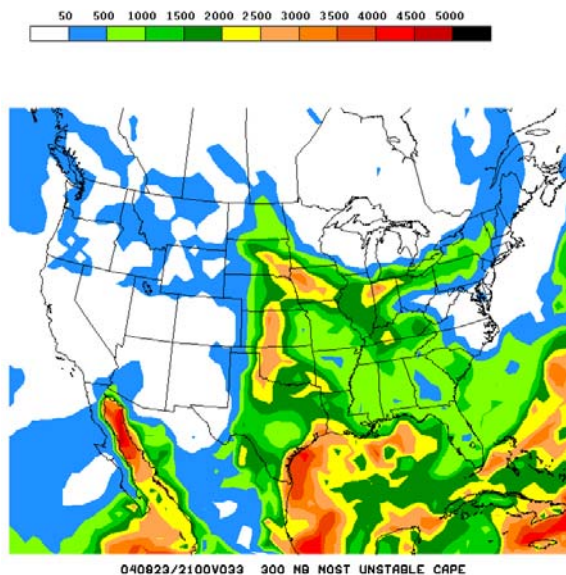


Fig. 16. 33-hour forecast of most unstable CAPE from the 1200 UTC operational 12-km Eta cycle of 22 August 2004.

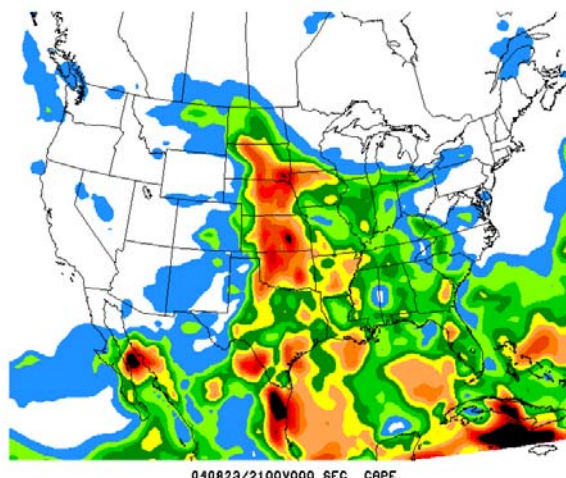


Fig. 17. 00-hr RUC CAPE analysis valid 2100 UTC 23 August 2004.

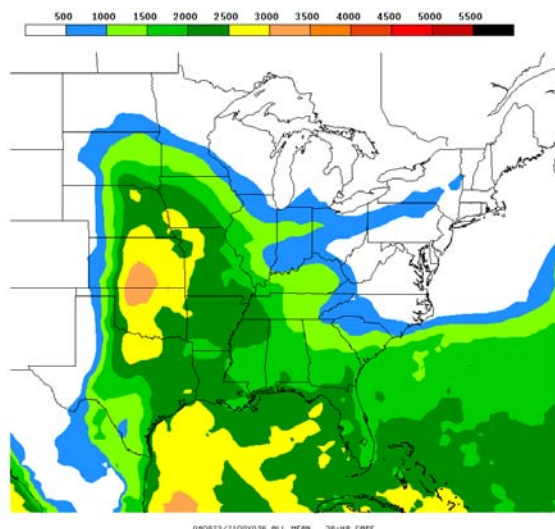


Fig. 18. 36-hr mean CAPE computed for all SREF members from the 09Z 22 August 2004 cycle.

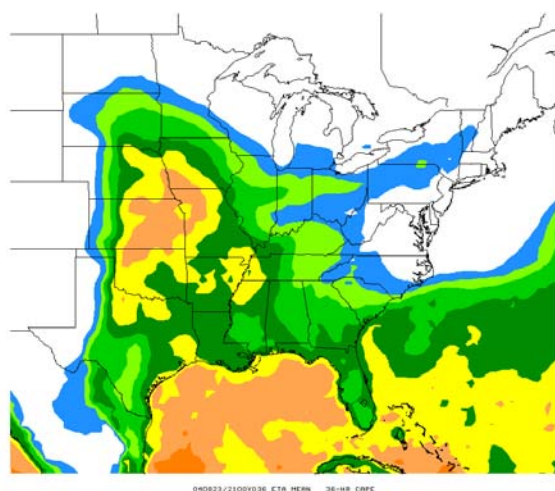


Fig. 19. Same as in Fig. 18, except for the mean of only the Eta members.

## 6 CONCLUSIONS

NCEP has implemented a new version of the SREF that attempts to better capture initial condition and model physics uncertainty. More spread in the solutions is found in this version of the system, compared to the previous configuration of the spread. With regards to precipitation forecasting, the warm season spread appears to be more realistic, but users of the system should be wary of using mean precipitation fields which will fail to show heavy amounts in situations in which the locations of maxima among the different members are spread out across a large area. This is

demonstrated in bias statistics showing a dry bias at heavier amounts for the ensemble mean but wet biases for individual members. Users are therefore encouraged to view precipitation solutions from all of the members instead of just looking at a mean field; if plots for all members are not available, spread should be examined closely as well as products showing the maximum precipitation among all members at all grid points.

For instability fields, the operational Eta has a low bias for CAPE due to issues with the shallow branch of the BMJ convective scheme as well as its tendency to initiate deep convection too quickly. The KF members, as well as some members with a modified BMJ scheme designed to delay triggering, appear to offset that bias quite nicely. Indications are that the RSM members may have a pronounced low CAPE bias.

News and updates on changes to the SREF system can be found at <http://www.emc.ncep.noaa.gov/mmb/SREF-Docs>.

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